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Dietary patterns of 5-year-old children and their correlates: findings from a multi-ethnic Asian cohort

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Abstract

There is limited data on the dietary patterns of 5-year-old children in Asia. The study examined childhood dietary patterns and their maternal and child correlates in a multi-ethnic Asian cohort. Based on caregiver-reported 1-month quantitative FFQ of 777 children from the Growing Up in Singapore Towards healthy Outcomes cohort, cluster analysis identified two mutually exclusive clusters. Children in the 'Unhealthy' cluster (43·9 %) consumed more fries, processed meat, biscuits and ice cream, and less fish, fruits and vegetables compared with those in the 'Healthy' cluster (56·1 %). Children with mothers of lower educational attainment had twice the odds of being assigned to the 'Unhealthy' cluster (adjusted OR (95 % CI) = 2·19 (95 % CI 1·49–3·24)). Children of Malay and Indian ethnicities had higher odds of being assigned to the 'Unhealthy' cluster (adjusted OR = 25·46 (95 % CI 15·40, 42·10) and 4·03 (95 % CI 2·68–6·06), respectively), relative to Chinese ethnicity. In conclusion, this study identified two dietary patterns in children, labelled as the 'Unhealthy' and 'Healthy' clusters. Mothers' educational attainment and ethnicity were two correlates that were associated with the children's assignments to the clusters. These findings can assist in informing health promotion programmes targeted at Asian children.

Key words: Children: Asian: Dietary patterns: Cluster analysis: Correlates

Diet is an essential contributor to children's health, growth and development. Establishing healthy diets early in life is important as they are the foundation for shaping the food preferences of children as they grow older[1,2]. Analysis of children's diets using a dietary pattern approach has been increasingly used, as this approach enables the evaluation of the whole diet as opposed to focusing on individual foods or nutrients.

To identify dietary patterns of a specific population, researchers have used dimension–reduction statistical methods to reduce complex dietary intake information into interpretable dietary patterns. One of the statistical methods is cluster analysis (CA), which assigns individuals into mutually exclusive clusters based on the concept of minimising differences of food intakes within-cluster and maximising differences of food intakes

Abbreviations: CA, cluster analysis; CH, Calinski–Harabasz; GUSTO, Growing Up in Singapore Towards healthy Outcomes; HEI-SGP, healthy eating index for pregnant women in Singapore.

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between-clusters. CA has been widely used in several studies to identify dietary patterns of children in recent years. For example, 'Processed', 'Plant-based' and 'Traditional British' dietary patterns were identified in children from the Avon Longitudinal Study of Parents and Children in the UK[3]. With regard to studies conducted in Asia, Choi *et al.*[4] have identified 'Korean' and 'Western' dietary patterns from the Gwacheon child cohort study in Korea. In the same vein, Shang *et al.*[5] have identified 'Healthy', 'Transitive' and 'Western' dietary patterns from children in five cities in China. In Singapore, while dietary data have been collected for 5-year-old children from the ongoing Growing Up in Singapore Towards healthy Outcomes (GUSTO) multi-ethnic birth cohort, the use of CA to investigate their dietary patterns has not been attempted. This is of particular interest as the pre-school period is crucial in influencing the long-term diet preferences of children[6]. Thus, the main objective of this study is to utilise CA to identify dietary patterns of 5-year-old children in this multi-ethnic Asian cohort.

The second objective is to examine the maternal and child characteristics associated with the identified dietary patterns. There is evidence to suggest differences in commonly consumed local food across the three main ethnic groups (Chinese, Indian and Malay) in the multi-ethnic population of Singapore[7], and we believe this extends to the children's diets as well. Besides ethnicity, socio-economic status may also influence the diet of children. The Avon Longitudinal Study of Parents and Children study, for example, found that lower socio-economic status was strongly associated with unhealthy dietary patterns in the children[3]. A similar association was also reported in China[5]. In addition, maternal diet might also influence the diet of children, as Bjerregaard *et al.*[8] reported that among participants of the Danish National Birth Cohort, maternal diet quality during pregnancy was an influential factor that affected their children's diet.

Whether similar associations hold true in this multi-ethnic Asian context or if other characteristics are related to the identified dietary patterns are of interest and were investigated in this study.

Materials and methods

This study utilised data from the GUSTO mother–offspring cohort study. The GUSTO study recruited pregnant Singapore citizens and permanent residents aged 18–50 years during their first trimester visits at two major public maternity units in Singapore (National University Hospital and KK Women's and Children's Hospital). To be eligible, a pregnant mother and her spouse must have the same ethnic background (Chinese, Malay or Indian, the three major ethnic groups in Singapore) and both must have parents of homogeneous ethnic background. The mothers must have had the intention to deliver in either of the two maternity units and plan to reside in Singapore for the next 5 years. Pregnant mothers with major health conditions (e.g. cancer, type 1 diabetes or psychiatric diseases) were excluded. The recruitment was conducted between June 2009 and September 2010. All recruited mothers and their spouses signed written informed consents. Children of these mothers were followed up from birth. For the current study, data from the child participants at 5 years of age were analysed. The complete GUSTO study design and protocol have been detailed elsewhere[9] and are registered as NCT01174875 at clinicaltrials.gov. Ethical approval of the study was obtained from the National Health Care Group Domain Specific Review Board (D/09/021) and the SingHealth Centralized Institutional Review Board (2009/280/D).

Dietary assessment of children

The children were aged 5 years (+0–3 months) when their diets were assessed between 2015 and 2016 using a quantitative FFQ. The FFQ was interviewer-administered to caregivers of the children by trained researchers during the scheduled year-5 GUSTO clinic visits. The FFQ encompasses 112 items consisting of single food/beverage items and mixed dishes (e.g. burger, fish ball noodle and chicken rice). The food list was developed with reference to dietary data of GUSTO children collected at earlier points of the cohort, and a local database was consulted to obtain the food composition of mixed dishes[10]. The caregivers were asked to report on the frequencies and quantities of food and beverage items consumed by their children in the previous month. The average servings of items consumed were ascertained using household measurements (e.g. slices of bread, boxes of raisins, pieces of chicken, etc.) or standard cups, spoons and plates presented during the interview. Further details of the FFQ are described in the evaluation study of the FFQ, where the FFQ was validated and found to have a reasonable level of agreement for a number of nutrients when compared against the reference diet records among 5-year-old child participants of GUSTO[11].

In addition to the FFQ, the caregivers were also asked several questions related to their children's diets. The questions included: 'Who is the primary caregiver of the child?'; 'Who is the food decision-maker of the child?'; 'When purchasing food, do you read the food labels?' and 'When purchasing food, do you read the Healthier Choice Symbols?'. The Healthier Choice Symbols are front-of-pack labels that are printed on food items that meet certain guidelines set by the Singapore Health Promotion Board[12]. For example, beverages with lower sugar contents and bread with higher whole-grain contents would have the symbols printed on the packaging.

Maternal and children's characteristics

Marital status, maternal education level, household income level and current pregnancy birth order were collected via interviewer-administered questionnaires during recruitment. The diet quality of the pregnancy diet, assessed during weeks 26–28 of gestation, was quantified with a healthy eating index for pregnant women in Singapore (HEI-SGP)[13]. The HEI-SGP evaluates certain food components (total vegetables; total fruit; total rice and alternatives; total protein foods; whole grains; dark green leafy and orange vegetables; whole fruit and dairy), nutrient compositions (percentages of energy intake from total fat and saturated fat) and the use of antenatal supplements. Mothers were subsequently classified into HEI-SGP tertiles, with mothers in the highest tertile having higher adherence to the Singapore dietary guidelines for pregnant women compared with mothers in lower tertiles. Details of the HEI-SGP can be found in Han *et al.*[13]

Sex of the children was recorded at birth. At the year-5 clinic visits, trained researchers measured the children's height and weight (stadiometer, model 213, Seca; and digital scales, model 803, Seca were used) in duplicates for accuracy. The children's BMI was calculated by dividing the body mass (in kg) by the square of the body height (in m). The WHO[14] age- and sex-specific BMI cut-off was used for overweight classification (BMI > 1 SD).

Statistical methods

Cluster analysis to identify dietary patterns. CA was performed to identify the children's dietary patterns. Input variables were energy-adjusted food intakes from the FFQ, expressed in g/1000 kcal. The objective of CA is to optimally assign children into distinct, mutually exclusive clusters by minimising differences of food intakes within cluster and maximising differences of food intakes across clusters[15]. The CA method used was K-medoids clustering, which employed the Partitioning Around Medoids algorithm[16]. Euclidean distances (direct/shortest distance between data points) were specified as the distance measure used for the Partitioning Around Medoids algorithm. The Partitioning Around Medoids algorithm was chosen because this algorithm is known to be less sensitive to outliers[17], which are often encountered if input variables are food intake data. Eight different cluster solutions were set to be evaluated, with the final cluster solution determined by comparing the Calinski–Harabasz index (CH index) across the eight possible solutions. The solution with the highest CH index is considered the most optimal solution based on the average between- and within-cluster sum of squares[18]. In addition, membership size and interpretability of the clusters were also considered[19].

The energy-adjusted food intakes of the clusters were presented by displaying median and interquartile range as the food intake data were not normally distributed. Food intakes with medians of zero (i.e. consumed by less than half of children) and skewed distributions were presented by displaying their 85th percentiles followed by 75th–95th percentiles. The clusters were then named interpretatively based on the combination of the foods that characterise the clusters. The median and interquartile range of energy and nutrients intakes of children in each cluster were also presented. These estimates were obtained by converting 1-month intakes (from FFQ) into daily intakes and analysed using Dietplan nutrient analysis software version 6 (Forestfield software) which contains a local database of energy and nutrient composition of food[10]. Mann–Whitney *U* test was used to assess the differences in food and nutrients intakes between the clusters.

Correlates of cluster dietary patterns. Logistic regression was used to evaluate the associations of maternal and child characteristics, responses to diet-related questions and year-5 BMI to the identified clusters. In the case of three or more clusters were to be identified, multinomial regression would have been used alternatively. The identified cluster with the largest membership was considered as a negative outcome, whereas positive outcome(s) were assignments of children to the remaining cluster(s). Bivariate strengths of associations were evaluated by computing crude OR (or Multinomial Relative Risk Ratios for ≥3 clusters) and their 95 % CI. Multivariable regression was subsequently performed to compute adjusted OR (or adjusted Multinomial Relative Risk Ratios) to account for confounding. All statistical analyses were evaluated assuming a two-sided test with an alpha of 0·05 and performed using Stata version 15 (StataCorp).

Results

A total of 808 caregiver-reported FFQ assessing the 5-year-old children's intakes were collected. The majority of caregivers were the children's mothers (92·6 % of FFQ), fathers (4·3 %), mother and father (0·6 %), with the remaining 2·5 % reported by non-parents (non-biological parents, grandparents, other family members or domestic workers); FFQ of twenty child participants were excluded as the reported energy intake was outside the predefined limits (500–4000 kcal/d)[11]. Eleven FFQ were further excluded due to implausible food intakes. The remaining 777 FFQ were available for analysis (Fig. 1), and this represented 76·8 % of 5-year-old children who were still registered in the GUSTO cohort.

The participants' characteristics are displayed in Table 1. In general, almost half of the children (48·4 %) were girls and were first-borns (44·8 %). Slightly more than half of the children were Chinese (56·6 %) with a fair representation of Malay (24·8 %) and Indian (18·5 %). Characteristics of the participants were largely similar to at the inception of the cohort, except for slightly lower proportions of Malay and Indian children in the present study, due to differences in loss to follow-up rates across ethnicities[9]. At year 5, 18·3 % of children were overweight, approximately two-thirds of children had their parents as their primary caregivers and more than half of parents reported reading food label when making food purchases ('Yes' or 'Sometimes' responses).

Dietary patterns identified by cluster analysis

The two-cluster solution was chosen after evaluating the CH indexes of eight different cluster solutions. The CH indexes for two-, three- and four-cluster solutions were 365·6, 269·2 and 204·0, respectively, with CH indexes of lower than 200·0 for the remaining solutions. The clusters' memberships of two-cluster solution were also suitable for further analysis, with the smaller cluster formed by 43·9 % of children.

The food groups that characterised the cluster dietary patterns are displayed in Table 2. They are presented as energy-adjusted daily intakes over a 30-d period. The identified clusters were interpretatively labelled as the 'Healthy' cluster and the 'Unhealthy' cluster. A total of 436 children (56·1 %) were assigned to the 'Healthy' cluster, while the remaining 341 children (43·9 %) to the 'Unhealthy' cluster. The 'Unhealthy' cluster was named such because children in this cluster consumed greater amounts of fries, processed meat, biscuits and ice cream – items with high contents of saturated fat and refined carbohydrates – compared with children in the 'Healthy' cluster. Those in

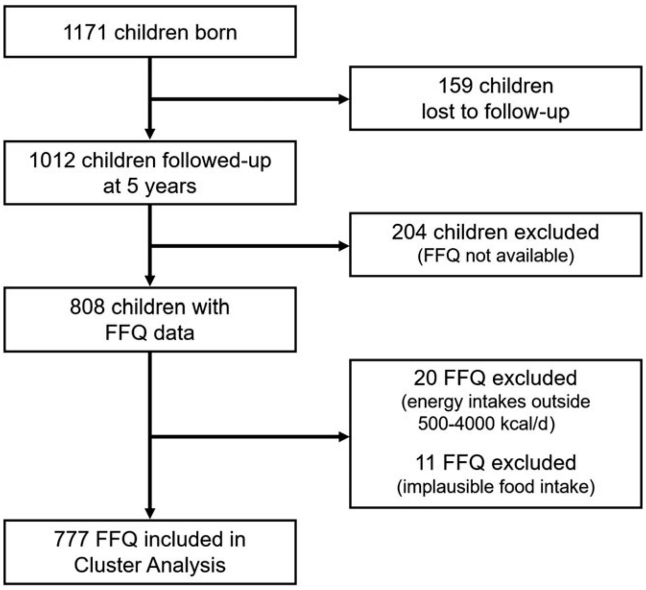

Fig. 1. Flow chart of included participants.

the 'Unhealthy' cluster also consumed lesser amounts of fish, fruits and vegetables compared with those in the 'Healthy' cluster. The distributions of the food groups between the clusters were found to be statistically significantly different for most of the food groups. No statistically significant differences between clusters were found for bun and ethnic bread, fried eggs, burger and pizza, low-fat milk and sugar-sweetened beverages food groups.

Energy and nutrients intakes

The energy and nutrients intakes of children assigned to the 'Healthy' and 'Unhealthy' clusters are displayed in Table 3. Children in the 'Healthy' cluster were found to have higher levels of energy-adjusted protein, fibre, fat, MUFA, PUFA, cholesterol, vitamin A and beta-carotene intakes compared with children in the 'Unhealthy' cluster. In contrast, children in the 'Unhealthy' cluster had higher intakes of energy and carbohydrate compared with children in the 'Healthy' cluster. No statistically significant differences between clusters were found for saturated fat, Na, Ca and Fe intakes.

Correlates of cluster dietary patterns

The correlates of the 'Healthy' and 'Unhealthy' clusters are presented in Table 4. Lower household income, lower maternal education level, being of Indian and Malay ethnicities, second- or subsequent-born children, BMI of 5-year-old children classified as overweight and lower HEI-SGP tertiles were found to increase the odds of children being assigned to the 'Unhealthy' cluster in the bivariate analysis. Meanwhile, all diet-related questions were not found to be associated with the cluster dietary patterns.

Ethnicity was associated with the children's cluster assignments, with Indian and Malay children have higher odds of being assigned to the 'Unhealthy' cluster, relative to Chinese children. After adjustment for confounders, ethnicity and maternal education level were the two variables associated with children's cluster assignments. For ethnicity, the adjusted OR (95 % CI) for Indian and Malay were 4·03 (95 % CI 2·68, 6·06) and 25·46 (95 % CI 15·40, 42·10), respectively, with Chinese as reference. Mothers whose educational attainment was secondary-level or below were found to have twice the odds of children being assigned to 'Unhealthy' cluster, with an adjusted OR (95 % CI) of 2·19 (95 % CI 1·49, 3·24), relative to mothers whose education were tertiary-level.

Discussion

This study is the first to report the dietary patterns of 5-year-old children of three ethnic groups in Singapore, utilising data from the ongoing GUSTO mother–offspring cohort study. CA identified two clusters, the 'Healthy' and 'Unhealthy' clusters. The dietary pattern of the 'Healthy' cluster was characterised by higher intakes of fruits, vegetables and fish and thus adheres closely to dietary recommendations[20]. In contrast, the 'Unhealthy' cluster appears to be the antithesis of what a healthy diet a child should follow and consisted of higher intakes of white bread, processed meat, ice cream and sweets. Another interesting finding was that the choice of protein sources differed between the clusters. The protein sources of children in the 'Healthy' cluster were mainly from fish, non-fried poultry, tofu and non-fried red meat. These food items were consumed less often by children in the 'Unhealthy' cluster. The opposite was true for processed meat – considered as less healthy protein sources, due to high-fat and Na contents – with higher intakes among children in the 'Unhealthy' cluster compared with the 'Healthy' cluster.

When comparing our cluster findings with other cohorts of children with similar age group, some similarities and some differences in the dietary patterns' characteristics were observed. Closely similar to the Avon Longitudinal Study of Parents and

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Table 1. Participants' characteristics
(Number and percentages)

Variables	Total participants (*n* 777)		Chinese participants (*n* 440)		Indian participants (*n* 144)		Malay participants (*n* 193)	
	n	%	*n*	%	*n*	%	*n*	%
Maternal characteristics								
Maternal age at 1st trimester pregnancy*								
<40 years	738	95·0	418	95·0	140	97·2	180	93·3
≥40 years	29	5·0	22	5·0	4	2·8	13	6·7
Household income								
≥SGD 6000	215	29·6	170	41·7	35	26·3	10	5·4
SGD 2000–SGD 5999	401	55·1	197	48·3	76	57·2	128	68·8
<SGD 2000	111	15·3	41	10·0	22	16·5	48	25·8
Maternal education level								
Tertiary-level	547	71·1	331	75·9	112	78·9	104	54·5
Secondary-level or below	222	28·9	105	24·1	30	21·1	87	45·5
Marital status								
Married	735	96·6	418	96·8	136	97·8	181	95·3
Single/divorced	26	3·4	14	3·2	3	2·2	9	4·7
Participants' characteristics								
Sex								
Girls	376	48·4	215	48·9	73	50·7	88	45·6
Boys	401	51·6	225	51·1	71	49·3	105	54·4
Ethnicity								
Chinese	440	56·6	440	100·0	0	0·0	0	0·0
Indian	144	18·5	0	0·0	144	100·0	0	0·0
Malay	193	24·8	0	0·0	0	0·0	193	100·0
Birth order								
First-born	348	44·8	220	50·0	52	36·1	76	39·4
Second- or subsequent-born	429	55·2	220	50·0	92	63·9	117	60·6
Overweight at year 5†								
No	584	81·7	338	86·2	102	75·0	144	77·0
Yes	131	18·3	54	13·8	34	25·0	43	23·0
Diet-related questions at year 5								
Parent as primary caregiver								
Yes	534	68·7	286	65·0	105	72·9	143	74·1
No	243	31·3	154	35·0	39	27·1	50	25·9
Parent as food decision-maker								
Yes	586	75·4	295	67·1	128	88·9	163	84·5
No	191	24·6	145	32·9	16	11·1	30	15·5
Parent read food label when purchasing food								
Yes	321	41·3	148	33·6	87	60·4	86	44·5
Sometimes	183	23·6	113	25·7	28	19·4	42	21·8
No	273	35·1	179	40·7	29	20·1	65	33·7
Parent read Healthier Choice Symbols‡ when purchasing food								
Yes	376	48·4	193	43·9	90	62·4	93	48·2
Sometimes	187	24·1	106	24·1	27	18·8	54	28·0
No	214	27·5	141	32·0	27	18·8	46	23·8

Missing data: Overweight at year 5 = 62; Household income = 50; Marital status = 16; Maternal age = 10; Maternal education = 8.
* Mean of 31·1 (SD 5·2) years.
† Based on WHO age- and sex-specific classification, overweight defined as BMI > 1 SD.
‡ Healthier Choice Symbols are displayed in food items that meet certain guidelines set by the Singapore Health Promotion Board.

Children cohort of British children, our 'Unhealthy' cluster resembled their 'Processed' cluster, which was characterised by white bread, processed meat, snack food items, fizzy drinks and squash. Similarly, vegetables and fruits were important cluster-differentiating food items in both cohorts[3]. In contrast, our cluster findings were less similar to two other Asian cohorts of children. The Gwacheon child cohort study in Korea similarly found bread, cookies, crackers and chips to be cluster-differentiating food items between their 'Western' and 'Korean' clusters. However, unlike our findings, intakes of vegetables and fish between clusters were not cluster-differentiating in Korea[4]. In the Chinese Five Cities Study, children in the unhealthy 'Transitive' cluster consumed relatively high amounts of processed meat accompanied by high intakes of light-coloured vegetables[5], whereas in our 'Unhealthy' cluster, a combination of high processed meat intakes and low vegetable intakes was found. Taken together, these comparisons highlight that while dietary patterns across different populations may be broadly generalisable into healthy and unhealthy patterns, CA is important to better understand the specific make-up of these diets, based on local diets and cultural context of the population.

In our study, observed differences in nutrients intakes between clusters provided internal validation of the dietary patterns derived from CA[21]. The higher levels of dietary fibre,

Table 2. Intakes of 5-year-old children in the healthy cluster and unhealthy cluster over a 1-month period, presented as g/1000 kcal per d (Median values and interquartile range)

	Healthy cluster (*n* 436)		Unhealthy cluster (*n* 341)		
Food groups	Median	IQR	Median	IQR	*P**
White bread	5·1	0·6–11·3	12·0	5·2–22·7	**<0·001**
Wholemeal bread	11·3	6·9–23·0**	4·2	0–17·2**	**<0·001**
Spread†	0·9	0–2·3	2·3	0·8–4·2	**<0·001**
Buns, ethnic bread	20·0	9·6–36·9	17·1	9·1–30·7	0·189
Oat porridge	9·8	0–46·3**	0	0–24·9**	**0·006**
Cereal	0·8	0–2·5	2·3	0·5–4·8	**<0·001**
Rice, polished	99·6	61·5–144·2	122·9	81·0–179·8	**<0·001**
Rice, unpolished	34·8	7·2–80·6**	0	0–1·6**	**<0·001**
Rice, flavoured‡	11·8	0–22·2	15·2	8·2–27·6	**<0·001**
Rice porridge	20·0	0–47·7	4·1	0–15·9	**<0·001**
Noodles	23·1	10·2–41·1	12·9	6·3–26·3	**<0·001**
Pasta	8·1	0–21·5	0	0–12·5	**<0·001**
Fries	2·7	1·0–5·3	4·7	2·5–8·9	**<0·001**
Vegetables, starchy	4·7	1·2–10·8	1·9	0–5·8	**<0·001**
Vegetables, non-starchy§	8·8	3·5–16·8	1·8	0–5·1	**<0·001**
Vegetables, cruciferous, green leafy	11·9	5·4–23·5	2·1	0–6·1	**<0·001**
Lentils	0·8	0–3·9	0	0–0·7	**<0·001**
Tofu	4·4	0·1–10·4	1·2	0–4·1	**<0·001**
Mushrooms	0·4	0–1·9	0	0–0·2	**<0·001**
Fruits	79·3	46·9–121·5	45·3	22·2–81·7	**<0·001**
Poultry, non-fried	6·1	2·4–13	4·3	1·3–8·9	**<0·001**
Poultry, fried	0	0–2·5	2·2	0–5·3	**<0·001**
Red meat, non-fried‖	4·3	0·6–9·1	0	0–2·0	**<0·001**
Processed meat	8·9	3·5–15·4	14·5	7·0–26·5	**<0·001**
Fish, non-fried	7·5	3·4–14·9	2·2	0–5·5	**<0·001**
Fish, fried	3·0	1·3–6·7**	3·7	2·2–8·8**	**<0·001**
Seafood	2·8	1·7–6·6**	2·1	0·9–3·8**	**0·001**
Eggs, boiled	6·4	1·5–13·6	1·7	0–5·9	**<0·001**
Eggs, fried	5·8	0·9–12·9	5·7	0·8–12·1	0·627
Burger and pizza	2·9	0–7·4	2·6	0–7·3	0·823
Dim sum	14·9	7·0–37·1**	0	0–7·7**	**<0·001**
Cake	4·5	1·9–10·4	5·7	1·8–13·3	**0·022**
Biscuits	3·6	1·7–8·2	6·9	3·2–15·0	**<0·001**
Snacks, fried	0·4	0–1·7	0·7	0–2·9	**0·015**
Snacks, sweets	3·0	1·0–6·7	3·8	1·7–8·2	**<0·001**
Ice cream	2·8	0·3–7·0	4·2	0·6–9·4	**0·002**
Soup-based desserts	10·6	4·8–25·8**	3·1	0–13·0**	**<0·001**
Milk	211·1	91·5–321·2	241·5	119·7–347·4	**0·030**
Milk, low-fat	20·5	0–106·2**	14·0	0–58·0**	0·320
Malt drinks	14·7	0·1–42·1	22·4	7·0–59·8	**<0·001**
Yogurt	1·0	0–13·4	0	0–3·3	**0·002**
Cheese	1·7	0–5·1	0·6	0–3·8	**<0·01**
Cultured drinks	11·9	3·5–26·8	8·7	2·6–21·0	**0·019**
Sugar-sweetened beverages	20·8	6·5–45·0	23·8	8·3–48·9	0·116
Pure juice	23·8	14·2–57·1**	11·7	4·6–29·1**	**<0·001**
Low-energy beverages¶	4·5	0–23·3**	11·6	0–50·4**	**0·027**
Soyamilk	19·9	11·8–41·1**	16·0	7·6–40·1**	**0·010**

* Mann–Whitney *U* test, *P*-values of < 0·05 are formatted in bold.
† Butter, margarine, peanut butter, kaya spread, hazelnut cocoa spread.
‡ Rice cooked with coconut milk, rice topped with curry-based gravy, fried rice.
§ Carrot, pumpkin, tomato, cabbage, gourds, stalk vegetables.
‖ Beef, mutton, lamb, pork.
¶ Low-energy isotonic drinks, low-energy fruit flavoured drinks, reduced-sugar tea beverages.
** Food groups with median of zero and skewed distribution are displayed as 85th percentile (75th–95th percentile).

vitamin A and beta-carotene intakes in the 'Healthy' diet were expected as they reflected the higher intake of fruits and vegetables. The 'Unhealthy' cluster had higher levels of total energy and carbohydrates, as well as lower levels of healthier fats such as MUFA and PUFA, which are in line with the higher intakes of refined and processed intakes in this cluster.

Numerous studies have shown that the diet quality of children is closely related to parental socio-economic status with higher education and income leading to better diet quality of children[22–25]. We found that household income level and maternal educational attainment were related to the assignment of children to the 'Healthy' or 'Unhealthy' clusters in the bivariate model. However, after accounting for confounders, only educational attainment was found to be significant, with mothers who had secondary-level or below education having twice the odds of their children being assigned to 'Unhealthy' cluster, relative to mothers whose education were tertiary-level. The finding might be related to how mothers perceive the importance of diet for the

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Table 3. Energy and nutrient intakes of 5-year-old children in the healthy cluster and unhealthy cluster over a 1-month period, presented as intakes per day (Median values and interquartile range)

	Healthy cluster (*n* 436)		Unhealthy cluster (*n* 341)		
Nutrient (unit)*	Median	IQR	Median	IQR	*P*†
Energy (kcal)	1214	978–1487	1593	1251–2005	<**0·001**
Protein (g)	34·5	31·5–37·7	30·8	28·4–34·1	<**0·001**
Carbohydrate (g)	143·8	134·9–152·7	148·9	138·6–158·8	<**0·001**
Fibre (g)	7·2	5·7–8·6	5·7	4·8–7·0	<**0·001**
Fat (g)	31·0	27·5–33·9	28·9	25·5–32·9	<**0·001**
MUFA (g)	9·9	7·9–11·8	8·3	6·6–10·4	<**0·001**
PUFA (g)	4·1	3·4–4·9	3·3	2·8–4·1	<**0·001**
Saturated fat (g)	11·4	9·3–13·5	10·7	8·9–13·4	0·062
Cholesterol (mg)	114	79–151	94	67–127	<**0·001**
Na (mg)	837	718–969	856	694–1013	0·396
Ca (mg)	469	352–612	466	352–597	0·659
Fe (mg)	7·1	6·0–8·4	7·1	5·9–8·4	0·861
Vitamin A (μg)	324	256–405	268	214–332	<**0·001**
Beta-carotene (μg)	879	522–1435	344	148–567	<**0·001**

* Nutrient presented as unit/1000 kcal per d. For energy, presented as kcal/d.
† Mann–Whitney *U* test, *P*-values of < 0·05 are formatted in bold.

health of children or due to the differing ability of mothers to access health-related information[26,27].

There is growing evidence that a mother's diet, even during pregnancy, has a long-term influence on their children's diet quality[8]. We did find some evidence that lower maternal diet quality during pregnancy was related to children being assigned to the 'Unhealthy' cluster in the bivariate analysis, although the results did not reach statistical significance in the multivariable model. There was a suggestion of interaction between the HEI-SGP tertiles and ethnicity, with higher HEI-SGP tertiles leading to lower odds of children assigned to 'Unhealthy' cluster in a varying extent across ethnicities, but unfortunately, the current study was underpowered to evaluate these further. The value of HEI-SGP as a determinant of children's diet quality should be investigated further in the future birth cohorts.

In line with other studies[27,28], ethnicity was associated with children's assignments to either the 'Healthy' cluster or the 'Unhealthy' cluster. We found that children of Malay ethnicity had higher odds of being assigned to the 'Unhealthy' cluster, relative to Chinese and Indian ethnicities. However, we should note that these higher odds were also due to the small number of Malay children assigned to the 'Healthy' cluster. This association was slightly attenuated by educational attainment, suggesting that higher education level leads to healthier children's diets in this ethnic group. This finding was similar to the Singapore National Nutrition Survey of adults in 2010, where adults belonging to the Malay ethnic group tended to have lower intakes of fruits and vegetables[7]. It was rather difficult to compare our findings with other studies, due to the difference in children's ethnic compositions across studies. For example, the Amsterdam Born Children and their Development cohort in the Netherlands consisted of Dutch, Surinamese, Turkish, Moroccan and other ethnicities[27], and the Continuing Survey of Food Intakes by Individuals in the USA consisted of White, African American, Hispanic and other ethnicities[29]. Nevertheless, both Amsterdam Born Children and their Development and Continuing Survey of Food Intakes by Individuals have suggested that the children of non-majority ethnicities were having less healthy diets[27,29]. The closest similarities to GUSTO in term of ethnic composition were the Malaysia subset of the South East Asian Nutrition Survey study, with Chinese, Indian, Malay and *Orang Asli* (Malaysia indigenous ethnic groups) making up 19·1 %, 6·4 %, 59·1 % and 15·4 % of children, respectively[30]. However, the study investigated the eating habits of children (e.g. irregular mealtimes, snacking, fast-food intake) rather than employing the dietary pattern approach. Despite the methodological difference, the Malaysia South East Asian Nutrition Survey bears some similarities with our findings. In Malaysia, a greater percentage of Malay children consumed fast food once or more per week (10·9 % of Malay children), compared with Indian (10·6 %), *Orang Asli* (8·0 %) and Chinese (7·3 %)[30]. Thus, somewhat supporting our finding that ethnicity is associated with child assignment to the 'Unhealthy' cluster. This may point to some cultural influence on food choices and would warrant health promotion efforts targeting this. Another approach is to conduct a qualitative study to identify the barriers and facilitators across different ethnicities, therefore developing a culturally sensitive nutrition support programme.

Previous studies have demonstrated that parent as primary caregiver, parent as food decision-maker and food label reading habits lend to willingness to prioritise healthy diet during caregiving[22,23,31]. In this study, however, these were not associated with how children were assigned to the 'Healthy' or 'Unhealthy' clusters. This finding must be interpreted with caution, as it might be possible that social desirability bias affected the responses; the responses did not translate to actual food purchases; or a combination of both occurred. Busick *et al.*[32] have suggested that tracking food purchases through the collections of food receipts is a better way to evaluate the parental influence on pre-schoolers' diet quality. To verify the current finding, the suggested study design may be investigated in the future.

Strengths and limitations

The strength of this study lies in the use of quantitative FFQ which enables us to quantify the children intake more precisely. This enabled us to account for the differences in children's

Table 4 Participants' characteristics according to their cluster memberships, as well as crude and adjusted OR of children being assigned to the unhealthy cluster
(Numbers and percentages; odd ratios and 95 % confidence intervals)

	Healthy cluster (*n* 436)		Unhealthy cluster (*n* 341)		Crude		Adjusted	
Variables	*n*	%	*n*	%	OR	95 % CI*	OR	95 % CI*,†
Maternal characteristics								
Maternal age at 1st trimester pregnancy‡								
<40 years	418	95·9	320	93·8	Ref.		–	
≥40 years	18	4·13	21	6·2	1·52	0·80, 2·91	–	
Household income								
≥SGD 6000	164	40·3	51	15·9	Ref.		–	
SGD 2000–SGD 5999	198	48·6	203	63·4	**3·30**	**2·28, 4·77§**	–	
<SGD 2000	45	11·1	66	20·6	**4·72**	**2·88, 7·72§**	–	
Maternal education level								
Tertiary-level	345	79·9	202	59·9	Ref.		Ref.	
Secondary-level or below	87	20·1	135	40·1	**2·65**	**1·92, 3·65**	**2·19**	**1·49, 3·24**
Marital status								
Married	418	97·7	317	95·2	Ref.		–	
Single/divorced	10	2·3	16	4·8	2·11	0·94, 4·71	–	
HEI-SGP score‖								
Highest tertile	159	41·1	74	23·6	Ref.		–	
Middle tertile	122	31·5	111	35·5	**1·95**	**1·34, 2·85§**	–	
Lowest tertile	106	27·4	128	40·9	**2·59**	**1·78, 3·78§**	–	
Children's characteristics								
Sex								
Girls	221	50·7	155	45·5	Ref.		–	
Boys	215	49·3	186	54·5	1·23	0·93, 1·64	–	
Ethnicity								
Chinese	344	78·9	96	28·2	Ref.		Ref.	
Indian	69	15·8	75	22·0	**3·89**	**2·62, 5·80**	**4·03**	**2·68, 6·06**
Malay	23	5·3	170	49·8	**26·49**	**16·21, 43·26**	**25·46**	**15·40, 42·10**
Birth order								
First-born	219	50·2	129	37·8	Ref.		–	
Second- or subsequent-born	217	49·8	212	62·2	**1·66**	**1·24, 2·21**	–	
Overweight at year 5¶								
No	333	84·5	251	78·2	Ref.		–	
Yes	61	15·5	70	21·8	**1·52**	**1·04, 2·23**	–	
Diet-related questions at year 5								
Parent as primary caregiver								
Yes	302	69·3	232	68·0	Ref.		–	
No	134	30·7	109	32·0	1·06	0·78, 1·44	–	
Parent as food decision-maker								
Yes	112	74·1	79	23·2	Ref.		–	
No	324	25·9	262	76·8	0·87	0·63, 1·21	–	
Parent read food label when purchasing food								
Yes	164	41·6	132	37·7	Ref.		–	
Sometimes	99	25·1	68	21·2	0·85	0·58, 1·25	–	
No	131	33·3	121	37·7	1·15	0·82, 1·61	–	
Parent read Healthier Choice Symbols** when purchasing food								
Yes	192	48·7	153	47·7	Ref.		–	
Sometimes	94	23·9	81	25·2	1·08	0·75, 1·56	–	
No	108	27·4	87	27·1	1·01	0·71, 1·44	–	

Missing data: Overweight at year 5 = 62; Household income = 50; Marital status = 16; Maternal age = 10; Maternal education = 8.
* OR of children being assigned to Unhealthy cluster; statistically significant OR are formatted in bold.
† Model with maternal education level and ethnicity.
‡ Mean of 31·7 (SD 4·7) years for Healthy cluster and 30·2 (SD 5·6) years for Unhealthy cluster.
§ *P*-value < 0·001 for linear trend.
‖ HEI-SGP: Healthy eating index for pregnant woman in Singapore, categorised as tertiles.
¶ Based on WHO age- and sex-specific classification, overweight defined as BMI > 1 SD.
** Healthier Choice Symbols are displayed in food items that meet certain guidelines set by the Singapore Health Promotion Board.

portion sizes that affected the identification of the cluster dietary patterns. The second strength is the method used to generate the clusters. The Partitioning Around Medoids algorithm combined with the evaluation of clusters from both statistical and interpretability standpoints, as well as internal validation by nutrients would ensure that the cluster solution is reflective of the study population.

The findings in this report are subject to at least three limitations. First, the use of caregiver-reported FFQ may have introduced social desirability bias related to over-reporting of food perceived to be healthy and under-reporting of food perceived to be unhealthy. The use of direct observations method to address this limitation was not attempted due to logistical issues and potential rejections by parents, as having observers recording children's food intakes would be considered as rather intrusive. Second, non-response bias might have occurred since we did not manage to collect all of the year-5 children's FFQ. It is possible that some caregivers were unwilling to be interviewed if they thought their children's diets were unhealthy. Thus, the difference between the 'Healthy' and 'Unhealthy' clusters might be greater if we managed to collect all FFQ. Third, the current children may not be representative of the Singapore population, given that the participants were recruited from two maternity units. However, considering that the two maternity units are the largest in Singapore, serving both private and subsidised patients, selection bias was likely to be minimal.

Conclusion

This study utilised a CA that identified two mutually exclusive dietary patterns in 5-year-old Asian children, labelled as the 'Healthy' and 'Unhealthy' clusters. Compared with Chinese children, children of Indian and Malay ethnicities had higher odds of being assigned to the 'Unhealthy' cluster. Besides ethnicity, lower maternal education level was also associated with higher odds of children being assigned to the 'Unhealthy' cluster. These findings would be valuable in informing health promotion programmes targeted to improve the diet of Asian children.

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